Light-Driven Applications of Vertically Aligned Few-Layer MoS_2

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Introduction: Two-dimensional (2D) transition metal dichalcogenides (TMDs) materials have tremendous potential due to their attractive properties. Among TMDs, monolayer MoS_2 possesses a direct band gap in the visible region and hence can be suitable for multiple light-driven semiconducting applications. The MoS_2 contains Mo and S atoms which are bonded via the covalent bond and the layers are bonded together via van der Waals interaction. Recently, vertically aligned MoS_2 have attracted the attention of the scientific community due to the presence of large exposed edges along with visible band gap for the light-driven applications. In this work, we have successfully demonstrated the photodetection behavior and the surface enhanced Raman scattering (SERS) detection at sub-nano molar (10^{-10} M) concentration of R6G dye.

Experimental: The VFL-MoS_2 over p-type Silicon substrate was grown via chemical vapor deposition (CVD) technique using the precursors MoO_3 and sulfur (S) powders in a nitrogen atmosphere. The oxygen inside the quartz tube was removed by repeated pumping for the vacuum and flushing of N_2 gas. The growth temperature was at 750 °C for 10 min and was allowed to cool naturally. At the time of reaction, MoO_3 powder reduces by the S vapor to form MoS_2. The high density of nucleation sites on Si substrate is due to the higher amount of MoO_3. Further, the larger growth time also tends to merge 2D MoS_2 films in vertical direction to the substrate. The synthesized VFL-MoS_2 has been characterized via Raman Spectroscopy, Photoluminescence and Scanning electron microscopy (SEM) techniques.

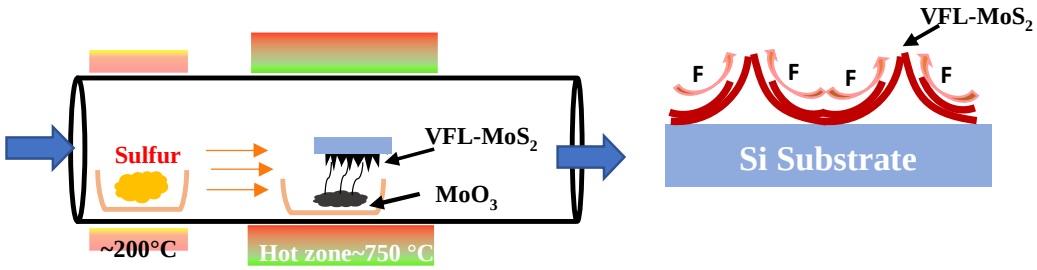

Figure 1. Schematic representation for the growth of VFL-MoS_2 and its mechanism.

Results and Discussion: We have successfully synthesized vertically oriented few-layer (VFL) MoS2 over a large area (1×1 cm2) on p-type Si substrate by using CVD method. The photodetection and SERS detection property of grown VFL-MoS2/Si is demonstrated for light driven applications. The good junction formation, highly exposed edges and the defect free film provides the high photoresponsivity of 7.37 A W-1 at -2.0 V bias under 0.15 mW cm-2 intensity of 532 nm. The high photoresponsivity of our heterojunction device can be ascribed to efficient electron-hole separation due to the formation of the high-quality p-n junction. The ultralow detection of R6G dye (10-10 M) is achieved due to the vibronic coupling existing in R6G/VFL-MoS2 system.